SOME ASPECTS OF CLIMATE FLUCTUATIONS IN MEXICO IN RELATION TO DROUGHT

E. JAUREGUI* AND D. KLAUS**

RESUMEN

Las fluctuaciones en gran escala de la precipitación en México durante los últimos cien años,se describen en función de las configuraciones de la circulación de altura. El método de las anomalías en estas configuraciones se usa para explicar los cambios en las trayectorias de los ciclones tropicales, que acompañan a los cambios de la circulación atmosférica y que producen una situación de sequía en México. Las tendencias de la lluvia en este país son así relacionadas con los cambios observados en la intensidad de los vientos superiores del oeste en latitudes medias.

ABSTRACT

Long term fluctuations in rainfall in Mexico, during the last 100 years are described in terms of the circulation patterns aloft. The metod of anomalies in these patterns is used to account for changes in the trajectories of tropical cyclons, which accompany the changes of the overall atmospheric circulation leading to a drought situation in Mexico. Rainfall trends in this country are thus related to the observed changes in the intensity of the upper westerlies at middle latitudes.

* *Instituto de Geografía, UNAM*

** *Instituto Geográfico, Univ. de Bonn, Alemania Federal*

INTRODUCTION

Variation in the climate are taking place over vast areas in the world. The most recent climatic fluctuation in the Sahel which has produced a prolongued drought has disrupted the economy in that region. The drought that plagued the Northeastern United States during 1962-65 is another well known climatic variation. Dry weather has also punished the Midwestern United States during the summer of 1974. In relation with this last case, during the last two years, extended periods of precipitation deficiencies have been observed during the rainy season in Northern Mexico.

The dry spells have caused serious loss of crops and livestock as well as reduction in water supply to urban areas in the Northern half of the country. At the same time, early fall freezing temperatures have damaged crops in the Mexican Plateau agricultural lands. The purpose of this paper is to describe some of the climatic fluctuations associated with drought (that is, prolongued periods of abnormally dry weather) that have occurred in Mexico since the end of the last century.

LONG TERM FLUCTUATIONS OF RAINFALL

In order to study recent rainfall trends data from 33 stations in Northern and Central Mexico have been used in this analysis. The most frequent period of the records is 1931-73. Smoothing was achieved by computing 10 and 5 years running-mean values. Fig. 1 shows the location of stations used. In fig. 2, 10 year-overlapping means of annual rainfall for several stations are shown. The only station with rainfall data since the 1870's is Mexico City (Tacubaya Observatory) on the southern edge of the area under consideration. Since it displays the same fluctuations for the period of 1931-73 as the other stations located further to the North, it can be taken as representative for the fluctuations that have occurred before; that is, since the end of the last century, in the whole region. The Mexico City rainfall curve shows that lowest values for the whole period occurred during the last decades of the 19th century. Rainfall amounts started to increase in the first 20 years of this century reaching a maximum around the mid 1920's until about the early thirties. Since then precipitation decreased gradually to a secondary minimum in the late 1940's and during the 1950's as can be appreciated in the curve for Mexico City, as well as in the rest of the other stations. From the 1960's on, rainfall increased steadily to a maximum during the mid and late sixties. Finally during these last years, in the early seventies, some stations in NW Mexico show a tendency towards decreasing rainfall. A very similar shape displays the curve when 10-year running means of annual rainfall are averaged for 12 stations distributed over NW and NE Mexico for the shorter period 1931-73. (figs. 3 and 4).The 20 year period 1943-62 lies below the average rainfall for the area (between 85 and 90% of normal). For NWestern Mexico precipitation shows a decrease during the last years. When a shorter period of overlapping averaging is considered the first half of the 1950's stands out as the driest years of the 20th century up to the present. (Fig. 5).

CIRCULATION PATTERNS LEADING TO DROUGHT IN MEXICO.

The drought -producing mechanisms are intimately tied to some characteristic circulation patterns that are observed over the area.

Drought conditions in Mexico are established during the summer when the middle and upper tropospheric circulation is dominated by a wave pattern consisting of an abnormally strong ridge over the mountains of western Northamerica and a closed anticyclonic cell centered over the Mexican Plateau. This cell is flanked by two pronounced troughs, one over the eastern Pacific, the other over eastern Northamerica extending across the Gulf of Mexico. (Fig. 6). At other times the anticyclonic cell and above normal heights are centered over the northern Gulf of Mexico. This unusually well developed cell is a westward extension of the Bermuda high.

This particular pattern provides an efficient mechanism for inhibiting the influx of moist rainbearing air masses from the Gulf of Mexico into Northeastern Mexico and also Central United States as has been pointed out by Namias (1955) and others. Also, under the dominance of this high pressure pattern the low-level moist surges of tropical Pacific air that provide sporadic rainfall to Northwestern Mexico are not likely to develop (see Hales, 1972).

Another feature common to this type of circulation in Mexico is the expansion and intensification of the Pacific high so that heights are above normal over the eastern Pacific. Interaction between the Bermuda and Pacific highs during drought conditions over the Midwestern United States, to the North of the Mexican border, has been mentioned by Tannehill (1947). In brief, summer time drought conditions in central and Northern Mexico depend in a large measure on the position, extent and development of the semipermanent upper level anticyclonic cells in the Atlantic and Pacific oceans.

DESCRIPTION OF PRECIPITATION ANOMALIES

Precipitation deficiencies were observed in the summers of 1952-54 over Central Northamerica. The prevailing patterns of large scale air flow and resulting patterns of temperature and precipitation over the United States for this period have been discussed by Namias (1955). Since the area under consideration lies just South of the region studied by this author, the patterns of circulation causing the drought in Northern Mexico are no doubt the same as those for the United States Midwest; that is, persistance of a great anticyclonic cell in the center of the continent and above-normal heights favoring descending motions and clear skies. (Fig. 6).

The three dry summers of 1952-54 in the United States analysed by Namias (Fig. 7) were also dry in Northern Mexico as can be seen in Fig. 8 where the rainfall for the three augusts 1952-54 appears down to 60% of normal. Within this three-year period there was a case of extreme dryness and that was the drought that occurred during october 1952; this was also according to Namias (1955) one of the driest months ever observed in the United States. At that time Northern Mexico lied under the domination of a strong anticyclone (at 700 mb) whose northern extension covered the western half of the United States (Fig. 6). The sinking air comprising the high-pressure cell resulted in abnormal warmth and lack of precipitation as can be appreciated in Fig. 9 where the percent of normal precipitation for October 1952 is shown. Large areas of Northern Mexico received no rainfall at all during this month, whereas others got only a small fraction of the normal precipitation.

HURRICANE ACTIVITY

A good proportion of the annual rainfall occurs in Mexico during the May-October period. Usually the deep moist trades are established in the area as the prevailing westerlies of the cold season migrate to the North. At the same time the Intertropical Convergence Zone moves northward to near the southern coasts of Mexico facing the Pacific Ocean. Apart from orographic rains, disturbances travelling in the tropical Atlantic air or originating in the tropical Convergence Zone in the Pacific are the main systems that bring substantial rainfall amounts to the Mexican land. When few tropical storms or hurricanes affect the coasts of the country, the rainy season is bound to be water deficient. Such was the case in 1952 when the number of hurricanes and tropical storms affecting Mexico was below normal.

Possible causes of fluctuations in hurricane activity in Mexican waters.

The average number of hurricanes and tropical storms either touching the Mexican coasts or passing a distance of less than 200 miles, is for the Atlantic and Pacific oceans 3 and 5 respectively. In 1952 no storms affected the Atlantic coasts and only three hurricanes approached the Pacific coasts without reaching land. During the 1950's Northatlantic tropical cyclones showed a tendency to move in a more northerly trajectory affecting the eastern Seaboard of the United States. This resulted in less storms reaching the Mexican Gulf coasts. At the same time, storms originating in the ITCZ affected the Pacific coasts of Mexico less frequently due perhaps to a more southerly position of the ITCZ. During the 1960's and beginning of the seventies the Atlantic hurricane trajectories have shown a tendency to follow a more southerly path bringing in general more moisture to Mexico as shown by the rainfall curves (see Fig. 2).

It has been suggested that in the last years there are signs of a return of the tropical Atlantic hurricanes following more northerly trajectories, which in turn would be the result of warm winters observed recently in the Atlantic coast of the United States. Warm winters in the eastern United States would mean below-average temperatures in Central and Northeastern Mexico during the cold season as cold air would flow down to the West of the trough centered over the Gulf of Mexico.

Indeed, the frequency of cold polar outbreaks over the Western Gulf of Mexico and adjacent coastal plains has considerably increased during these last years. The frequency of strong (between 70 and 100 km/hr) Northerly winds has correspondingly increased as can be seen for the Veracruz station on the southwestern Gulf coast (Fig. 10).

As a result of this recent change from zonal to more frequent meridional circulation in the area, winter precipitation has been increasing over Eastern Mexico (Fig. 11). A higher frequency of colder air masses sweeping over the Gulf of Mexico during the last years would probably leave colder waters over the western Gulf and therefore would minimize the opportunity for tropical disturbances to develop or intensify there.

Factors that are believed to be inhibiting for tropical cyclone development such as extensive upper-air westerlies and below-normal sea surface temperatures over large portions of the hurricane generating areas, have caused a decrease in the number of Atlantic hurricanes and storms since 1972 (see Hope, 1975; Simpson and Hebert, 1973; Hebert and Frank, 1974).

Since a large number of Atlantic systems often iniciate tropical storms in the Eastern Pacific (Frank, 1970) one would expect that in general a lull in the Atlantic hurricane activity would reduce also the number of storms on the Eastern Pacific. Over the Eastern Pacific also, an abnormal southern displacement of the upper westerlies would act as dissipating factor for hurricanes originating either in the ITCZ or the Atlantic. An abnormally strong east Pacific anticyclone could drive more to the South the cold water which up-wells along the Mexican coast from about 24° northwards. In the winter of 1972, for instance, the east Pacific anticyclone was abnormally strong (Namias, 1972) so that the 1973 drought in NW Mexico could have been related to this situation.

RAINFALL IN MEXICO AND CHANGES IN THE GENERAL CIRCULATION

Changes in rainfall patterns with time may be explained in terms of fluctuations in the general strenght of the global wind circulation which lately have caused meridional movements of the climatic zones. In Mexico rainfall fluctuations can be explained in terms of changes in the general wind circulation.

The low rainfall amount shown by the Mexico City curve in the last decade of the 19th century can be related to the low frequency of westerly types that was observed in the British Isles in the epoch of prominent blocking during the last quarter of the 19th century (Lamb, 1966; Kowal and Kassam, 1975). In relation to this period Kraus (1955) found that tropical rainfall decreased abruptly at the end of the last century which according to this author was due to a contraction of the rainy belt (and a shortening of the dry season).

The considerable increase in seasonal rainfall in Mexico from the turn of the century until 1925-1930 can be associated with stronger trade wind circulation over Mexico as a result of the general shifting to the North of the subtropical high pressure cells as pointed out by Wallén (1955). This shift would explain the strengthening of the westerlies in the 1920's as has been observed by Lamb (1966, 1968, 1972).

After the 1930's the decrease in rainfall in Mexico could be attributed to the southward movement of the subtropical cells in the Northern Hemisphere that has been lately reported (Lamb, 1972; Winstanley 1973).

During the decade of the 1960's rainfall amounts increased in general over the area reaching in some cases unprecedent peak values, as shown by the Mexico City curve. This part of the curves could not be explained in terms of meridional movements of the high pressure cells, but rather as a result of longitudinal displacements of the troughs lying between them. Thus, the wetness in Mexico during the sixties could possibly be attributed to a westward shift of the trough that normally lies to the East of the Atlantic coast of Northamerica and penetrates deep into the tropics. This same westward shift of the Atlantic trough is suspected to have increased precipitation over the Rocky Mountains (Lamb, 1966) during the 1960's. Indeed, the lowering of the 700 mn surface during those years over the area, suggests that there has been a longitude shift to the West (Fig. 12).

CONCLUSIONS

The rainfall trends just examined can be regarded as no more than a first glimpse of an aspect of climatic changes in the present century over Northern Mexico demanding more investigation.

As everywhere else, rainfall fluctuations in Mexico can be related to changes in the general global wind circulation. Two precedents for the present observed tendency towards a dry period in NW Mexico can be identified and these are the decades at the turn of the century which were the driest of record and the one from the mid 1940's to the mid-1950's. The drought of the recent early 70's in NW Mexico does not appear to be up to the present, as intense and persistent as the two previous ones.


ATIL
C. GUERRERO
QUIRIEGO
MINAS
CHINIPAS
PAPASQUARO
LERDO
ARIZPE
BURGOS
F. MADERO
MATEHUALA
TROPIC OF CANCER
GULF OF
MEXICO
PACIFIC
OCEAN
ZACATECAS
S. ELENA
S.L.P.
TAMPICO
GUADALAJARA
JALAPA
IXTLAHUACAN
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FIG. 1

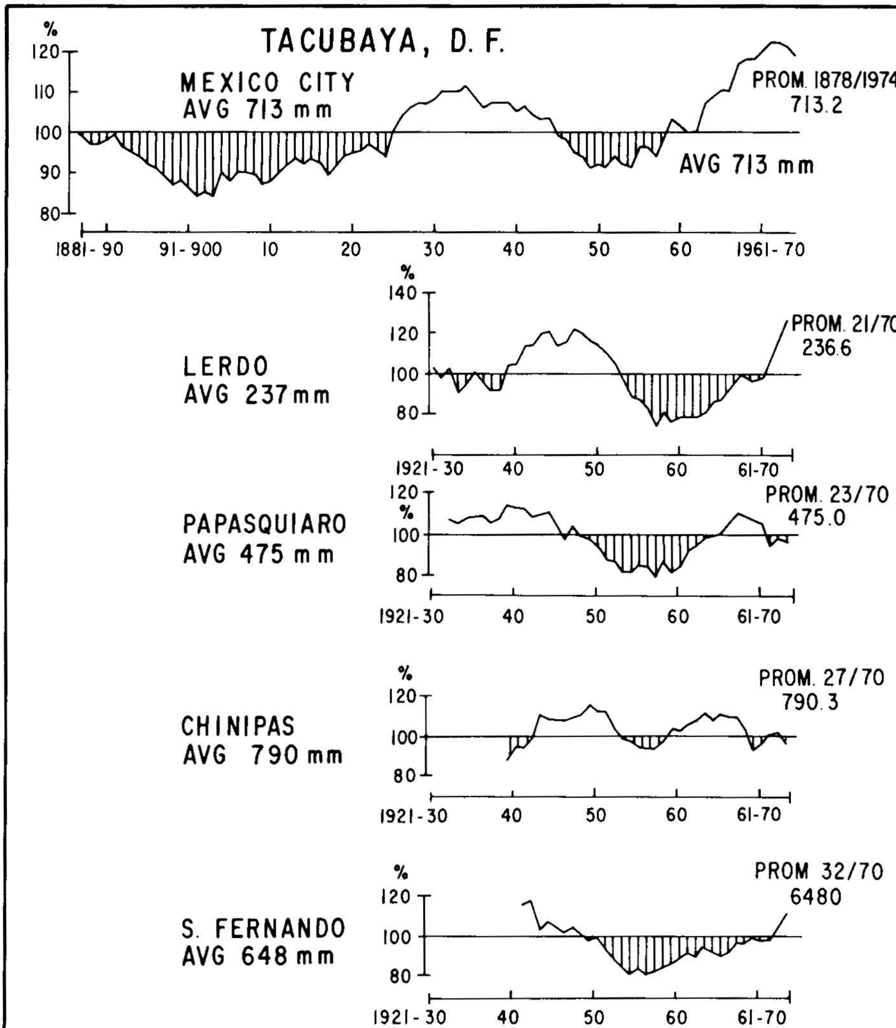

FIG. 2 TEN-YEAR RUNNING MEANS OF ANNUAL RAINFALL (IN % NORMAL)

FIG. 3

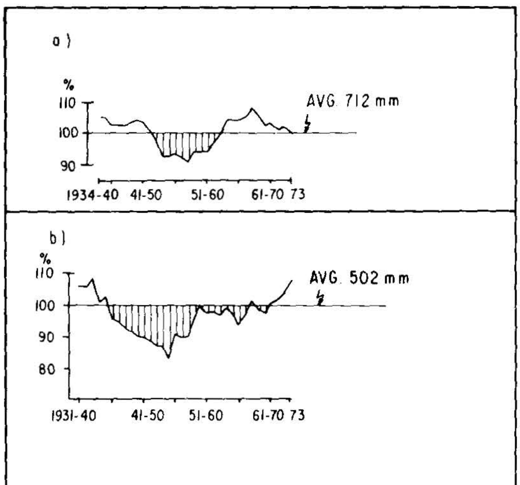

FIG. 4 TEN-YEAR RUNNING MEANS OF ANNUAL RAINFALL FOR 6 STATIONS IN NW a). AND NE b). MEXICO.

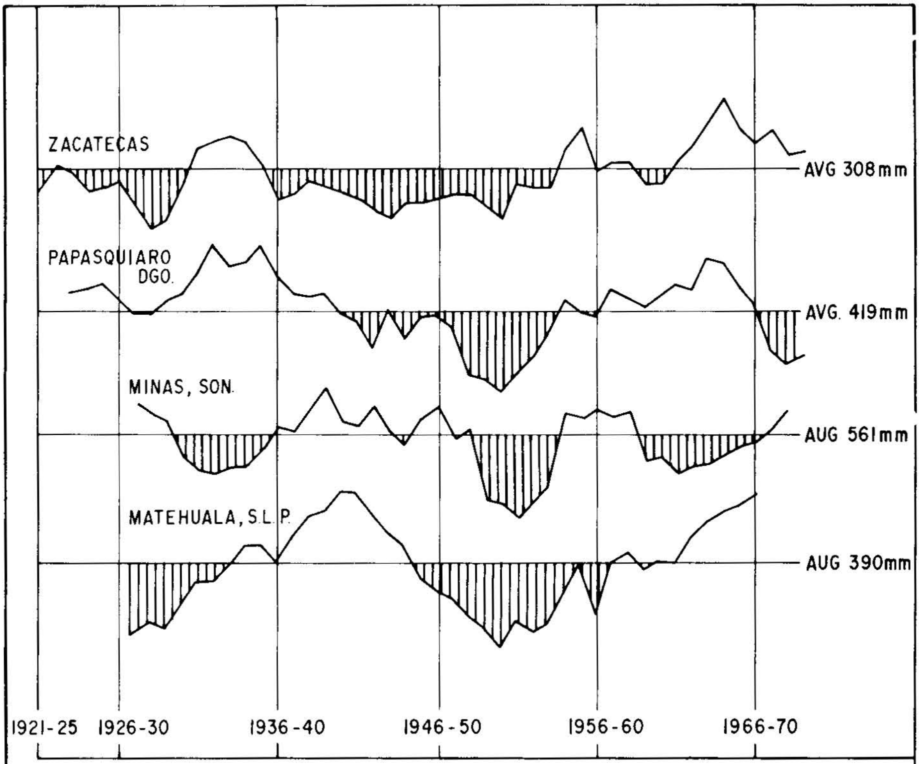

FIG. 5 FIVE - YEAR RUNNING MEANS OF MAY - OCT. RAIN FALL

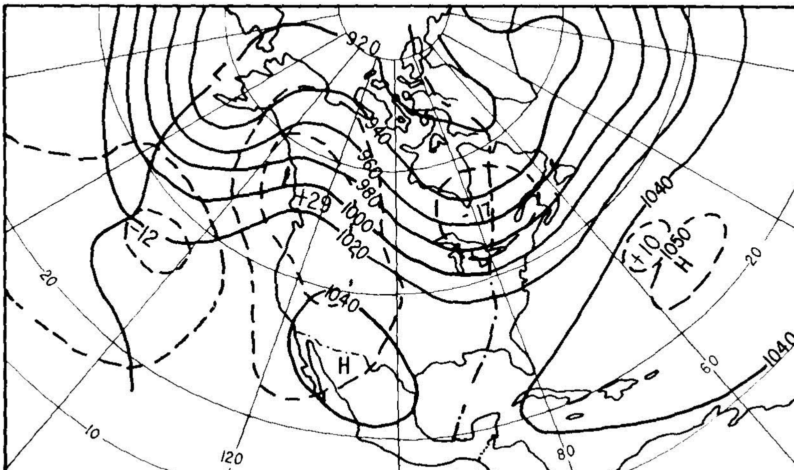

FIG. 6 MEAN 700 mb CHART FOR OCTOBER 1952

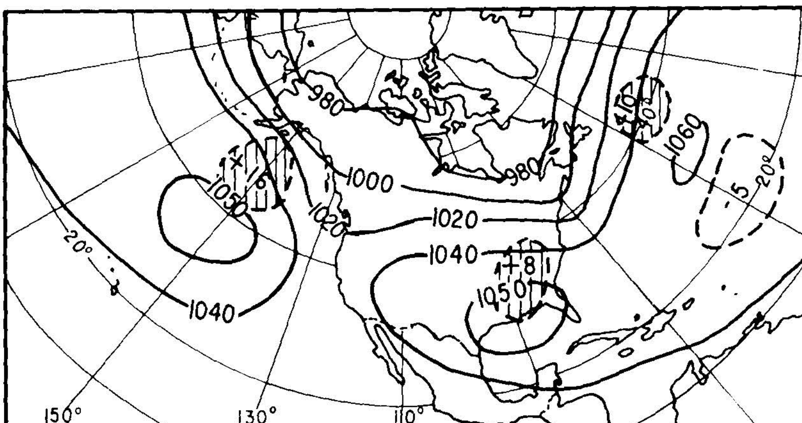

FIG. 7. MEAN 700 mb CONTOURS FOR THREE SUMMERS 1952-54 (AFTER NAMIAS, 1955).

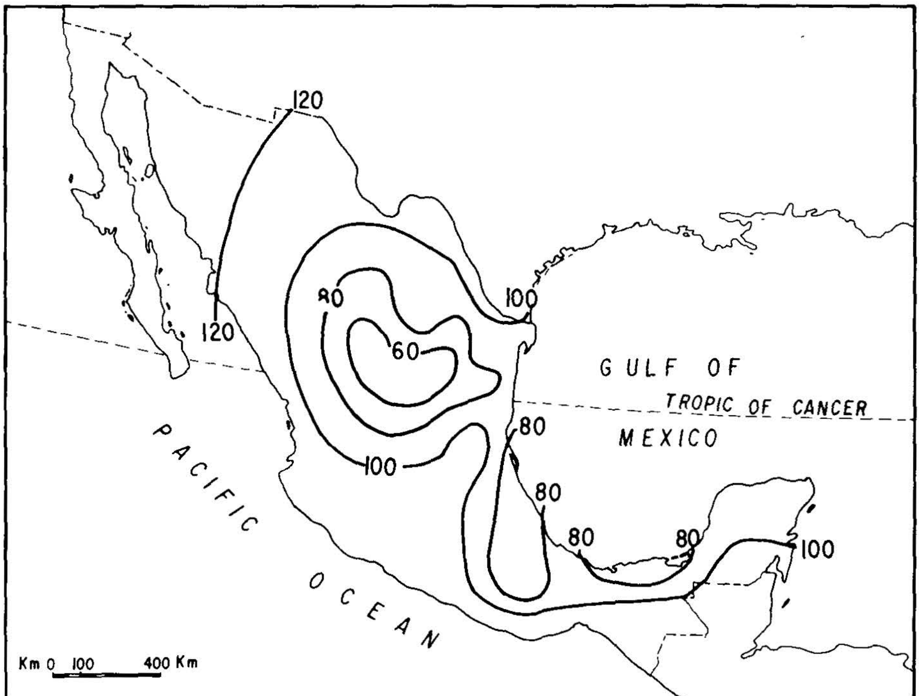

FIG. 8. PERCENT OF NORMAL RAINFALL FOR 3 AUGUSTS 1952 - 1954.

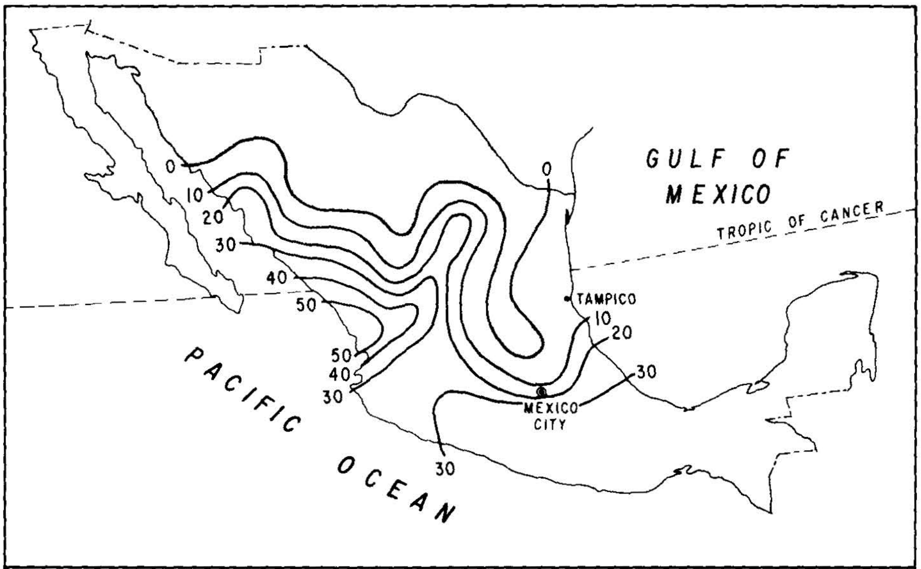

FIG. 9 PERCENT OF NORMAL RAINFALL FOR OCTOBER 1952

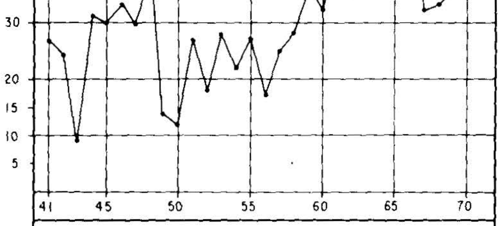

FIG. 10. ANNUAL FREQUENCY OF STRONG (70 TO 100 KM/HR) NORTHERLY WINDS AT VERACRUZ.

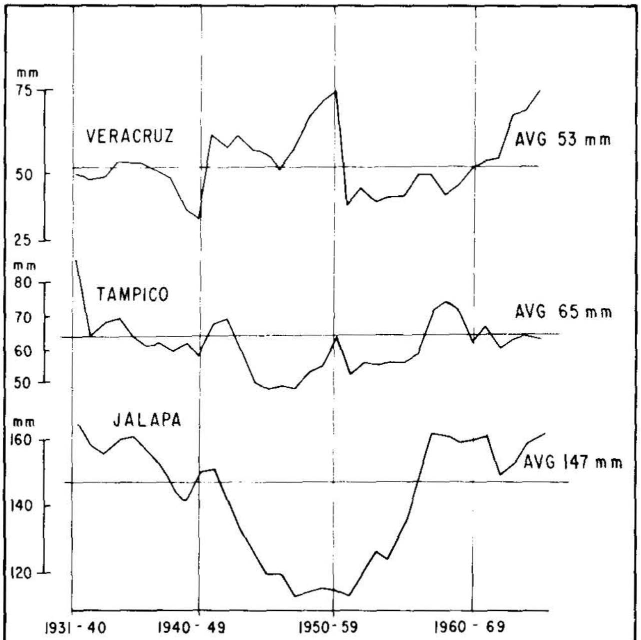

FIG. 11 TEN-YEAR RUNNING MEANS OF WINTER (JAN-MAR) RAINFALL.

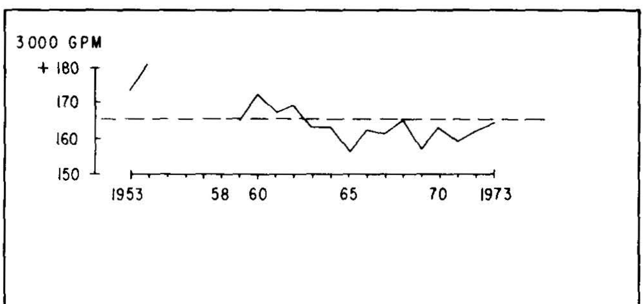

FIG. 12. MEAN (JUN - SEP) 700 mb SURFACE HEIGHTS FOR SAN DIEGO, EL PASO AND BROWNSVILLE.

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